STRATIGRAPHY, COMPOSITION AND AGE OF CUBAN RUDIST-BEARING DEPOSITS

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ABSTRACT

Along the NE flank of Cuba, parts of the Bahamian carbonate platform are exposed, while in the central part of the island a Cretaceous volcanic arc sequence is present. Rudist assemblages are found in both of these major tectonic settings.

Three levels of rudist faunas have been found in the Bahamian carbonate platform: (1) a lower Aptian assemblage, described here for the first time, is associated with a localized platform margin facies in the Gibara area. It includes *Amphitriscoelus waringi* Harris and Hodson, *Offneria* sp. cf. *O. interrupta* Paquier, *Caprina douvillei* Paquier, and ?*Pachytraga paradoxa* (Pictet and Campiche). (2) A Cenomanian level includes unidentified rudist fragments in calciturbidites with planktonic microfossils, in the Sierra de Cubitas. (3) In the same area, a Maastrichtian assemblage is associated with platform marginal facies, and includes *Biradiolites lombricalis* (d'Orbigny), *Titanosarcolites* aff. *alatus* Chubb, *Antillocaprina* sp., *Mitrocaprina* sp., and orbitoidal foraminifers.

There are four levels of rudist-bearing limestone associated with the Cretaceous volcanic arc sequence. Three of them are found as dark-coloured limestone intercalations in the volcano-sedimentary suite, while the fourth and youngest level lies with angular unconformity on the previous suite: (1) an upper Albian level is characterized by *Tepeyacia corrugata* Palmer, *Kimbleia albrittoni* (Perkins), ?*Texicaprina* sp. and *Caprinuloidea multitubifera* Palmer. Earlier references in the literature to *Sabinia* sp., and *Ichthyosarcolites* sp., as well as to other coalcomaninid species appear to be erroneous, though some of the last group need checking. (2) A ?Santonian fauna is known from Loma Yucatán (Camagüey) and central Cuba. This includes two, possibly synonymous, species of *Durania, D. curasavica* (Martin) and *D. lopeztrigoi* (Palmer), as well as *Vaccinites inaequicostatus macgillavryi* (Palmer), *Torreites tschoppi* Mac Gillavry, *Praebarrettia corrali* (Palmer), and plagioptychids. (3) A widespread Campanian fauna includes *Barrettia monilifera* Woodward, *Torreites sanchezi* (Douvillé), *Parastroma sanchezi* (Douvillé), *Biradiolites cubensis* Douvillé, *B.* sp. (group of *B. acuticostatus* [d'Orbigny]), *Bournonia* sp., *Plagioptychus* sp., *Mitrocaprina* sp., as well as other, minor taxa. Also included in this fauna is the distinctive species widely referred to in earlier studies as *"Durania" nicholasi* (Whitfield), but which is designated here as the type species of a new genus, *Macgillavryia*. An important new find is the discovery of rare *Titanosarcolites alatus* associated with this fauna, thus extending the range of that taxon into the Campanian. (4) An uppermost Campanian-Maastrichtian level represents post volcanic arc platform deposits with varying facies and assemblages. Either *Titanosarcolites giganteus* (Whitfield) or *Antillocaprina* spp., may be particularly abundant, together with *Mitrocaprina tschoppi* (Palmer), *Praebarrettia sparcilirata* (Whitfield), *Barrettia multilirata* Whitfield (of which *B. gigas* Chubb is a probable synonym), *Parastroma guitarti* (Palmer), *Hippurites mullerriedi, Macgillavryia nicholasi, Biradiolites lombricalis* (?syn. *B. mooretownensis* Trechmann), *B.* sp. (group of *B. acuticostatus*), *Bournonia* spp., and some other, minor taxa.

On the Bahamian platform, conditions may have favoured the growth of rudists for most of Cretaceous time, but outcrops of the rudist-bearing facies are limited, due to tectonic superposition of the sections. Within the exposed Cretaceous platform sequences, lagoonal deposits, without rudists, predominate. In the volcanic arc sequences, by contrast, there were apparently only three main phases of limestone deposition suitable for the growth of rudists during the active evolution of the arc. The extinction of the volcanic arc in the mid-Campanian was followed by the extensive development of sheet-like marl and limestone deposits with rudists (especially *Titanosarcolites*) during latest Campanian-Maastrichtian times.

Key words: Cretaceous, rudists, Cuba, stratigraphy, taxonomy, Bahamian platform, Cretaceous volcanic arc.

RESUMEN

A lo largo del flanco NE de Cuba, están expuestas partes de la plataforma carbonatada Bahamiana, mientras que en la parte central de la isla está presente una secuencia de arco volcánico cretácico. Los conjuntos de rudistas están en estos dos marcos tectónicos mayores.

En la plataforma calcárea Bahamiana hay tres niveles de fauna de rudistas: (1) Un conjunto del Aptiano temprano, que se describe aquí por primera vez, asociado con facies de margen de plataforma del área Gibara; incluye *Amphitriscoelus waringi* Harris y Hodson, *Offneria* sp. cf. *O. interrupta* Paquier, *Caprina douvillei* Paquier y ?*Pachytraga paradoxa* (Pictet y Campiche). (2) Un nivel cenomaniano en la Sierra de Cubitas; contiene fragmentos no identificados de rudistas en calciturbiditas con microfósiles planctónicos. (3) En la misma área, un conjunto maastrichtiano asociado con facies de margen de plataforma; incluye *Biradiolites lombricalis* (d'Orbigny), *Titanosarcolites* aff. *alatus* Chubb, *Antillocaprina* sp., *Mitrocaprina* sp. y foraminíferos orbitóididos.

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Existen cuatro niveles de caliza con rudistas asociados a la secuencia del arco volcánico cretácico. Tres de ellos están en intercalaciones de caliza oscura en la serie volcano-sedimentaria, en tanto que el cuarto y más joven nivel descansa con discordancia angular en la serie anterior. (1) Un nivel Albiano superior se caracteriza por *Tepeyacia corrugata* Palmer, *Kimbleia albrittoni* (Perkins), *?Texicaprina* sp. y *Caprinuloidea multitubifera* Palmer. Algunas referencias antiguas en la literatura que mencionan a *Sabinia* sp. e *Ichthyosarcolites* sp. y a otras especies de coalcománidos parecen ser erróneas, aunque algunas requieren revisión. (2) Una fauna santoniana se encuentra en Loma Yucatán (Camagüey) y en Cuba central. Incluye dos especies de *Durania*, *D. curasavica* (Martin) y *D. lopeztrigoi* (Palmer), que posiblemente sean sinónimos, así como a *Vaccinites inaequicostatus macgillavryi* (Palmer), *Torreites tschoppi* Mac Gillavry, *Praebarrettia corrali* (Palmer) y plagioptíquidos. (3) Una fauna campaniana muy extendida incluye *Barrettia monilifera* Woodward, *Torreites sanchezi* (Douvillé), *Parastroma sanchezi* (Douvillé), *Biradiolites cubensis* Douvillé, *B.* sp. (grupo de *B. acuticostatus* [d'Orbigny]), *Bournonia* sp., *Plagioptychus* sp., *Mitrocaprina* sp., y otros taxa menores. Incluida en esta fauna se encuentra la especie notable, frecuentemente citada en trabajos anteriores como *Durania nicholasi* (Whitfield), que aquí se designa como especie tipo del nuevo género *Macgillavryia*. Un hallazgo importante es el descubrimiento del raro *Titanosarcolites alatus* asociado con esta fauna, que extiende el alcance de este taxon al Campaniano. (4) Un nivel del alto Campaniano tardío-Maastrichtiano representa depósitos de plataforma post-arco volcánico con conjuntos y facies variables.

Titanosarcolites giganteus (Whitfield) o bien *Antillocaprina* spp. pueden ser particularmente abundantes junto con *Mitrocaprina tschoppi* (Palmer), *Praebarrettia sparcilirata* (Whitfield), *Barrettia multilirata* Whitfield (de la que *B. gigas* Chubb es un probable sinónimo), *Parastroma guitarti* (Palmer), *Hippurites mullerriedi*, *Macgillavryia nicholasi*, *Biradiolites lumbricalis* (? sinónimo *B. mooretownensis* Trechmann), *B.* sp. (grupo de *B. acuticostatus*), *Bournonia* spp. y algunos otros taxa menores.

En la plataforma Bahamiana, las condiciones debieron ser favorables para el desarrollo de rudistas la mayor parte del Cretácico, pero los afloramientos con rudistas son limitados debido a la superposición tectónica de las secciones. Dentro de las secuencias expuestas de plataforma cretácica, predominan los depósitos lagunares sin rudistas. En las secuencias de arco volcánico, por el contrario, hubo aparentemente tres fases principales de depósitos de caliza adecuados para el crecimiento de rudistas durante la evolución activa del arco. A la extinción del arco volcánico en el Campaniano medio, siguió el desarrollo extenso de depósitos de caliza y marga en forma de láminas delgadas con rudistas (especialmente *Titanosarcolites*) desde fines del Campaniano tardío hasta el Maastrichtiano.

Palabras clave: Cretácico, rudistas, Cuba, estratigrafía, taxonomía, plataforma Bahamiana, arco volcánico.

INTRODUCTION

Cuban rudist palaeontology has a long tradition, beginning with the discovery of rudist fossils by De la Torre (1915) and following with the taxonomic works of Sánchez-Roig (1926), Douvillé (1926, 1927), Palmer (1933), Rutten (1936b), Thiadens (1936a, 1936b, 1936c), Mac Gillavry (1937), Vermunt (1937a, 1937b), Keijzer (1945), van Wessen (1943), Hermes (1945), Albear (1947) and Müllerried (1951). Along with the identification of taxa, these authors established the basic stratigraphic framework for the rudist-bearing rocks of Cuba. During the early sixties, two important papers were published dealing with the identification and age of Cuban rudist assemblages (De la Torre, 1960; Chubb, 1961), basically using the data collected by early workers without any additional field work. More recently, during the 1:250,000 scale mapping of Cuba, the stratigraphy of rudist-bearing units was revised and renewed collection and identification of rudist fossils was carried out (Lupu, 1975; De la Torre *et al.*, 1978; Iturralde-Vinent and De la Torre, 1990).

Nevertheless, the Cuban collections of more that 650 rudist specimens in the palaeontological collections of the Museo Nacional de Historia Natural of Cuba (MNHNH-P) and the Institute of Geology and Palaeontology (IGP), which include much type material, remained without a comprehensive revision. In order to revise the collection, all the localities were relocated on the 1:50,000–1:250,000 geological maps and the stratigraphical positions and ages of several rudist-bearing deposits were re-evaluated. Additionally, some of these locali-

ties were revisited in the field in order to verify the actual composition of the assemblages and their stratigraphic context. Also, as part of authors' work, the taxonomy of the specimens in the collections and in the revisited localities was re-assessed, and several misidentifications were found. This work has not concluded, as will be evidenced later, because several dubious localities have not yet been revisited. During this study, it was found that some important ages and taxa were not sufficiently represented in the collections, so that some localities that had not been examined for over 45 years were visited, in order to collect and improve the authors' knowledge on them. It is a considerable credit to the diligence of some of the earlier field geologists that so many of their collection sites could be accurately relocated.

Consequently, a revision of the stratigraphical position, age, and taxonomy of the Cuban rudist faunas, is presented, as a contribution to the IGCP Project 364 "Correlation of the Caribbean ophiolites and volcanic arcs". The authors hope that this paper will be useful for further correlation of the volcanic arc sections throughout the Greater Antilles.

GEOLOGICAL SETTING

Cuba is a complicated cluster of tectonic terranes accreted as a fold-belt during latest Cretaceous to middle Eocene times, unconformably overlain by slightly deformed deposits of latest Eocene to Recent age. Within the fold-belt there are several major tectonic units of continental (sialic) and oceanic crustal character. The continental units include the Meso-

Cenozoic Bahamian platform deposits, in the north, and several allochthonous terranes located in western and southcentral Cuba. The oceanic units are ophiolites, the Cretaceous volcanic arc and the Palaeogene volcanic arc (Iturralde-Vinent, 1994) (Figure 1).
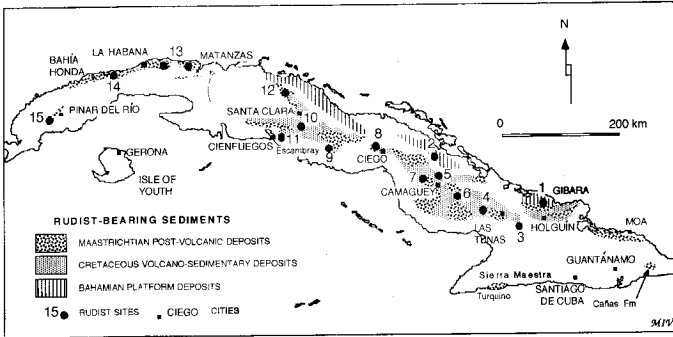

Figure 1. Main outcrops of Cuban rudist-bearing deposits and pertinent localities discussed in text.

Mesozoic and Cenozoic deposits of the Bahamian platform are present along the northern margin (and extending northwards) of Cuba. These rocks are strongly deformed and crop out in several hilly and coastal plain areas along the northern half of the island (Figure 1). The geology of this unit has been described by Meyerhoff and Hatten (1968, 1974), Khudoley and Meyerhoff (1971) and Puscharovsky (1988). In general terms it is composed of a northern platform section and its southern palaeoslope. The carbonate platform was developed on a Lower Jurassic to lowest Cretaceous siliciclastic and evaporite unit, and comprises Aptian to Maastrichtian shallow-water limestones and dolomites of the Remedios Group (Figure 2). The southern palaeoslope deposits are of deep-water facies and are more strongly deformed than those of the platform (Iturralde-Vinent, 1994). The rudist-bearing sediments of the platform sequence are recorded at three levels (lower Aptian, Cenomanian and Maastrichtian), though only Maastrichtian examples are known within the southern palaeoslope sequence. As the platform is strongly deformed and the sections superimposed by thrusting, it is possible that the lack of rudist-bearing deposits of ages other than those recorded here, is due only to the limited availability of adequate outcrops.

The oceanic tectonic units (comprising the ophiolites and the Cretaceous volcanic arc) have been emplaced over the southernmost part of the Bahamian platform deposits and are exposed mostly in the central part of Cuba (Figure 1). Here rudist-bearing limestones are found in two stratigraphic settings: the Cretaceous volcanic arc sequence, and the overlying post-arc platform sequence. The sequence is composed of Aptian (or older) to Campanian volcano-sedimentary rocks with flows, necks and dikes of tholeiitic to calc-alkaline composition and dark-coloured, rudist-bearing limestone intercalations of late Albian, ?Santonian and early-middle Campanian ages. Among those limestone levels are volcanic rocks of
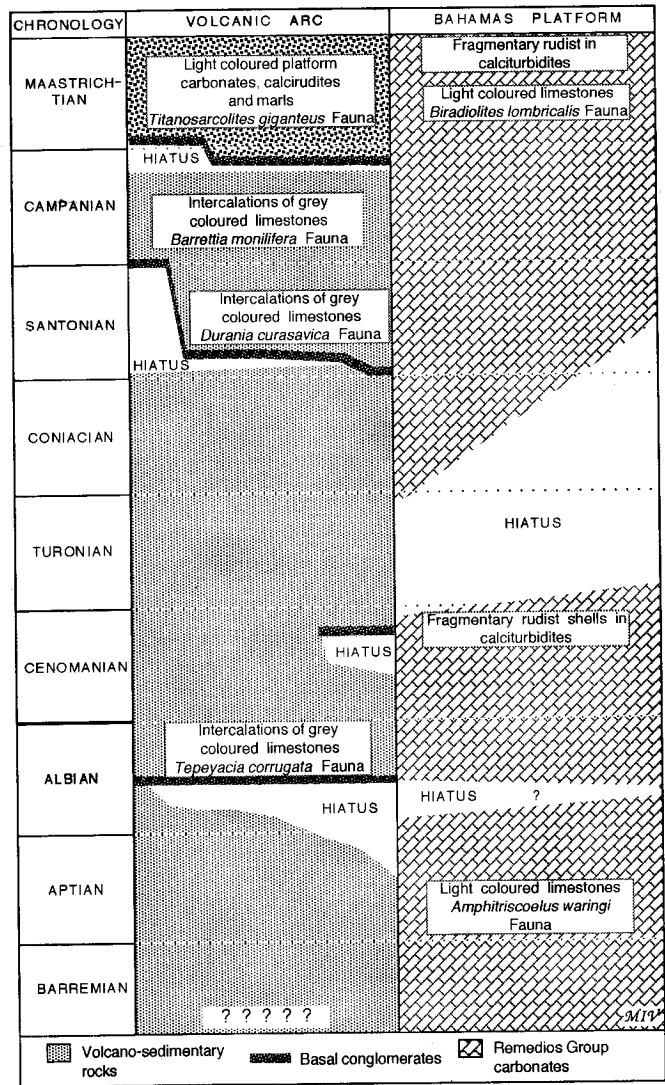

Figure 2. Stratigraphic positions of the rudist-bearing deposits of the Cretaceous volcanic arc and the Bahamian platform.

intermediate ages (Figure 2; Meyerhoff and Hatten, 1968; Khudoley and Meyerhoff, 1971; Pardo, 1975; Iturralde-Vinent, 1994). The consistency in age and stratigraphical position of these limestones in different areas of Cuba suggests that their development was probably related with sea level changes and/or with episodes of decline in the volcanic activity of the arc. Unconformably overlying the deformed volcanic arc sequence are widespread uppermost Campanian to Maastrichtian siliciclastic and carbonate deposits (Figures 1 and 2). The carbonate rocks here are of typical platform facies, with rudists.

THE RUDIST-BEARING DEPOSITS

Although many lithostratigraphical terms have been applied to the rudist-bearing units of Cuba, the nomenclature followed here is that from the geological map of Cuba, scale 1:250,000 (Puscharovsky, 1988), with some minor necessary modifications.

LOWER APTIAN

The first lower Aptian rudists from Cuba were recently reported by Rojas and others (1992). They have been recovered from only a single locality—Tumbadero—in the Alturas de Gibara, a low range of hills located between the towns of Gibara and Floro Pérez (Auras), in the province of Holguín (Figure 1, locality 1). This important new fauna will be described in greater detail in a later paper.

Grey-weathering, cream coloured bioclastic grainstones to packstones are here exposed, with up to half metre-thick bands containing abundant worn and fragmented shells of rudists, gastropods and corals, with algal coatings. Falling within the Remedios Group (Bermúdez, 1950; emended Díaz and Iturralde-Vinent, 1981), which crops out in several localities along the northern margin of Cuba, this facies is interpreted as having developed on the outer margin of the Cretaceous Bahamian carbonate platform.

Amphitriscoelus, the most abundant genus, is identified by the characteristically broad, "bean-shaped", form of the combined accessory cavity and posterior tooth socket in the right valve (Plate 1, figure 1), and the presence of simple pallial canals in both valves, absent from their ventral margins (Plate 1, figures 1, 2). Despite some specimens being relatively large and thick shelled, the material seems assignable to *A. waringi* Harris and Hodson. Masse and Rossi (1987) have recognized this species as a lower Aptian marker, believing it to have been endemic to a south Caribbean faunal province. However, the present record, together with others recently reported from Mexico (Alencáster and Pantoja-Alor, 1993) show its endemism to have been more broadly Caribbean. Associated with it here are other distinctively lower Aptian taxa, including *Offneria* sp. cf. *O. interrupta* Paquier (Plate 1, figure 3), *Caprina douvillei* Paquier and *?Pachytraga paradoxa* (Pictet and Campiche). These, however, are otherwise well known from Old World Tethyan sites (see Masse, 1985), though *C. douvillei* has also been recorded from the Sligo Formation in the subsurface of Texas (Skelton, 1982), as well as from Huetamo, in SW Mexico (Alencáster and Pantoja-Alor, 1993).

UPPER ALBIAN

Early reports of "Albian-Cenomanian" or even "Cenomanian-Turonian" rudists, from a few localities in central Cuba, were provided by Thiadens (1936c), Mac Gillavry (1937) and Hermes (1945), but this fauna is assigned here to the upper Albian as discussed later. Rudist-bearing limestones of this age are always found in Cuba as intercalations within the lower part of the volcano-sedimentary island arc sequences (Figure 2).

According to the authors' observations, Hermes's localities H222, F235a and F235c, located SW of Guáimaro (Figure 1, locality 4), are in a lens of poorly stratified, pale to dark grey but locally reddened, recrystallised bioclastic limestone, about

1 km long and 40–50 m thick (Figure 3). The lens is embedded within basalts, but the basal contact is erosional, indicating that the rudist-bearing limestones were deposited during a magmatically quiescent period, probably on top of an eroded volcanic centre. An Aptian-Albian assemblage of microfossils has been recognized from this localitiy by Consuelo Díaz (personal communication, 1993; Table 1). This volcano-sedimentary sequence belongs to the Guáimaro-Camujiro Formation, from which the foraminifers *Hedbergella* sp. and *Ticinella* sp. have been reported elsewhere (Iturralde-Vinent and de La Torre, 1990).
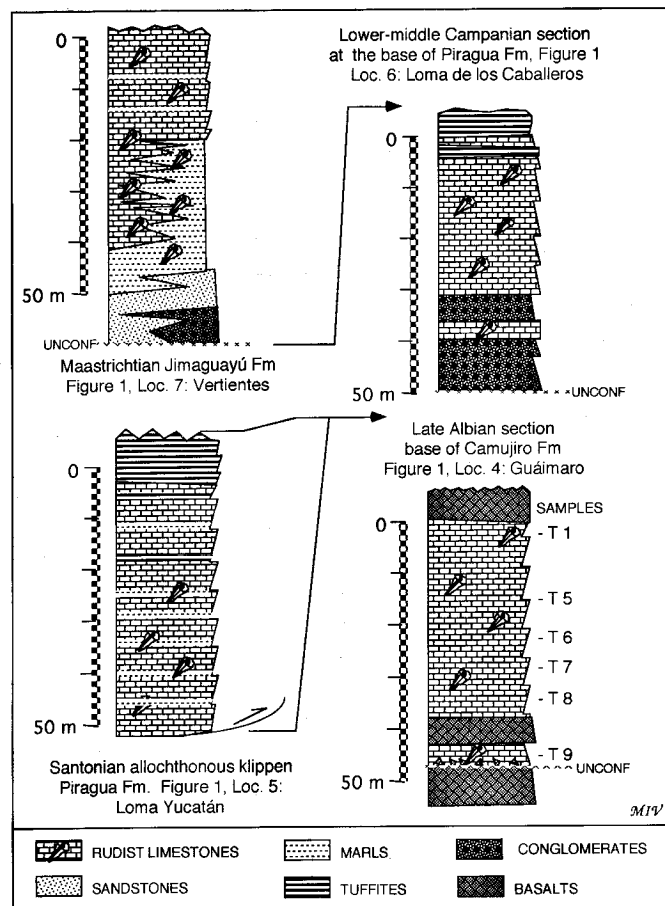

Figure 3. Synoptic stratigraphical sections of selected rudist-bearing limestone localities of different ages within the Cretaceous volcanic arc sequence in Camagüey Province, central Cuba.

The rudists reported from these localities by Hermes (1945) were *Ichthyosarcolites*? sp., *Sabinia* sp., *Caprinuloidea perfecta* Palmer and *Tepeyacia corrugata* Palmer. Only the last-named species is confirmed from our own collections and field observations here (Plate 1, figure 4). The presence of a small *arête cardinale*, a feature that Chubb (1971) had called into question, can be confirmed, as well as the two distinctly infolded radial bands (Palmer, 1928). Otherwise, *Kimbleia albrittoni* (Perkins) has been identified, with its characteristically oval cross-sectional outline and dorsally situated tooth in the right valve, shown in Plate 1, figures 5 and 6 (see
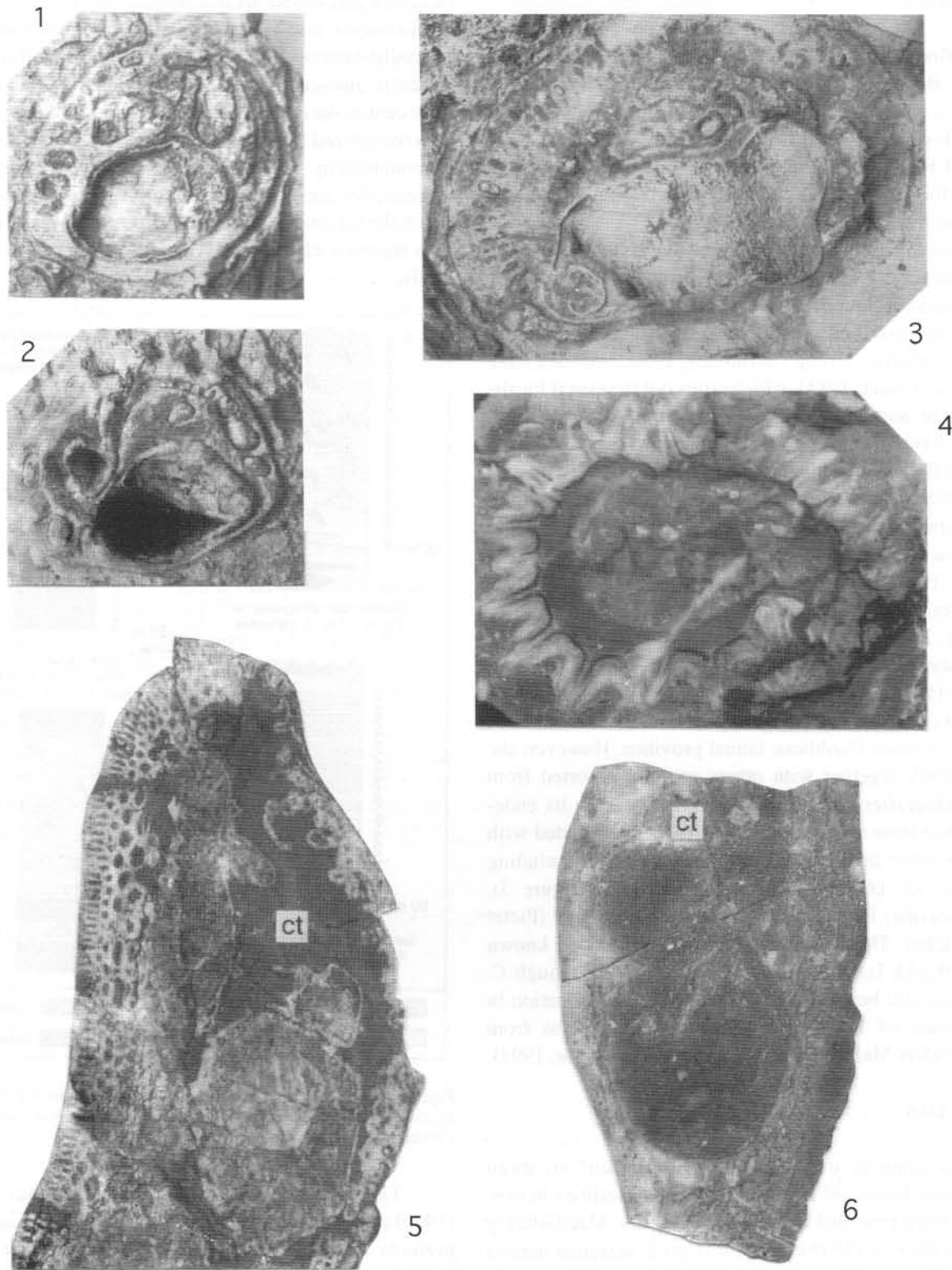
Plate 1. Repositories of figured specimens: MNHNH-P, Palaeontological collections of the Museo Nacional de Historia Natural, La Habana, Cuba; PWS, collections of P.W. Skelton; NHML, Natural History Museum, London, UK. Figures 1, 2—*Amphitriscoelus waringi* Harris and Hodson. *1*, right valve, MNHNH-P 92/1.9 (x 1.0); *2*, left valve, PWS 92/1.14 (x 1.5), both in adapical view of commissural plane. Lower Aptian, Gibara, Holguín (Figure 1, locality 1). Figure 3—*Offneria* sp. cf. *O. interrupta* Paquier, right valve in adapical view of commissural plane, PWS 92/1.10 (x 1.1). Lower Aptian, Gibara, Holguín (Figure 1, locality 1). Figure 4—*Tepeyacia corrugata* Palmer, adapical view of section across right valve, MNHNH-P 696 (x 1.5). Upper Albian, Guáimaro, Camagüey (Figure 1, locality 4). Figures 5, 6—*Kimbleia albrittoni* (Perkins), sections across right valves; *5*, oblique abapical view of dorsal part (posterior to left), with much of inner shell, including central tooth (ct) leached out and replaced by dark micrite, PWS 92/2x (x 1.0); *6*, adapical view (posterior to right), central tooth (ct) partly obscured by stylolitization, PWS 92/2.1 (x 1.0). Upper Albian, Guáimaro, Camagüey (Figure 1, locality 4).

Table 1. Microfossils identified in thin section by Consuelo Díaz (personal communication, 1993), from locality 4 in Figure 1 (SW of Guáimaro). See Figure 3 for location of samples.

Microfossils	T9 base	T8	T7	T6	T5	T1 top
Bacinella sp.						*
Bacinella irregularis	*			*		*
Clypeina sp.		?	?			
Hedbergella sp.						*
Hedbergella trocoidea			cf.		*	
Ataxophragmiidae					*	*
Cymbaloporiidae	?		?	*		
Salpingoporella sp.					*	
Permocalculus inopinatus					*	
Radiolaria						*

Coogan, 1973). The present authors believe that it was to examples of this species that the name "*Sabinia*" was erroneously applied; and they have also found a specimen of ?*Texicaprina* sp. (Plate 2, figure 1), showing large pallial canals of polygonal section throughout the shell (see Coogan, 1973). Again, the earlier reports of "*Ichthyosarcolites*?" may be an erroneous reference to this taxon. The genus *Caprinuloidea*, however, does appear to be represented (Plate 2, figures 2, 3), although the species seems more closely referable to *C. multitubifera* Palmer, than to *C. perfecta*: at least five rows of pallial canals of polygonal cross-section appear to be present in the valve wall (see Coogan, 1973). These various large coalcomaninid caprinids are of recumbent form, in the morphotype classification of P.W. Skelton and E. Gili (see Skelton, 1991). They are apparently not preserved in life position, because even the whole valves are somewhat worn, and have thin algal coatings, implying that they are at least parautochthonous. *T. corrugata*, by contrast, is locally abundant in life position at certain levels, at this site, forming small elevator clusters.

Elsewhere, *K. albrittoni* is known only from upper Albian strata, as, for example, in the Upper Aurora Limestone of the Sierra de Tlahualilo, Coahuila, Mexico, as well as in the Edwards Group (Washita Division) and equivalents in Kimble, Pecos and Val Verde Counties, Texas (Coogan, 1973), where it is associated with intrashelf basin bank deposits together with ?*Texicaprina* and *Eoradiolites* (Scott, 1990). An association of *Kimbleia* with *Texicaprina*, *Caprinuloidea* and other rudists, including various radiolitids, has also been noted by Alencáster (1987) from platform margin deposits of probable late Albian age in the El Doctor Formation, in the area of Jalpan, Querétaro, Mexico. Otherwise, *Texicaprina* is regarded as middle-upper Albian and *C. multitubifera* as middle Albian to lower Cenomanian (Coogan, 1973; Scott, 1990). All considered, a late Albian age thus seems most likely for the Guáimaro rudist limestone.

In the former Las Villas Province—now known as Villa Clara, Cienfuegos and Sancti Spiritus provinces—Albian rudists have been reported from several localities between the Escambray Mountains and Santa Clara city (Figure 1, locality 10). The present authors were unable to visit these localities together, but, according to the literature and personal experience of the second author, the rocks exposed are dark limestones intercalated in a volcano-sedimentary sequence. Different formational names have been given to these rudist-bearing limestone units (Meyerhoff and Hatten, 1968; Pardo, 1975; Kantshev *et al.*, 1976; Puscharovsky, 1988), but they are referred to collectively here as the Provincial Formation.

The Provincial Formation has been described by these authors as comprising dark to pale grey, partially nodular bioclastic limestones, intercalated with marl, shale and conglomerate associated with volcanic rocks. Rudists have been reported mostly from the base of the sequence. The limestones become thinly bedded towards the top, where they contain abundant ammonites of late Albian to Cenomanian age. These limestones also yield planktonic foraminifera: *Hedbergella* spp., *Clavihedbergella* sp. cf. *C. simplex*, *Ticinella roberti* and radiolaria: *Cenosphaera* sp., *Flustrella* sp. The unit reaches more than 100 m in thickness, and is widely distributed north of the Escambray Mountains (Kantshev *et al.*, 1976). The limestones are interpreted here as representing a sort of isolated carbonate platform that evolved during a period of relative volcanic quiescence, because they are now found as thick lenticular beds of limited lateral extent within the volcanic section.

From different localities of the Provincial Formation, Palmer (1933), Thiadens (1936a, 1936b, 1936c) and Kantshev and others (1976) have reported *Tepeyacia corrugata*, *Caprinuloidea perfecta*, *Caprinuloidea* sp., *Coalcomana ramosa* (Boehm) and *Sabinia* sp., though in the light of our findings in Camagüey, this list merits revision. The likely identity of the last-named taxon has already been commented above.

These assemblages have been referred to as the *Tepeyacia* Fauna (De la Torre, 1960; Chubb, 1961) or the *Tepeyacia corrugata* Fauna (Iturralde-Vinent and De la Torre, 1990). Initially dated as Cenomanian-Turonian (De la Torre, 1960; Chubb, 1961), the Albian age of the fauna was later recognised by Chubb (1971) and Iturralde-Vinent and De la Torre (1990). As noted above, a late Albian age now seems likely for the sites described previously.

There are intriguing parallels, as well, with the fauna of the Seafield Limestone of Jamaica, from which Chubb (1971) reported "*Sphaerucaprina seafieldensis* Chubb", "*Sabinia totiseptata* (Palmer)" (= ?*Texicaprina*: see Coogan, 1973), *Caprinuloidea perfecta* and *Tepeyacia multicostata* Chubb. Chubb regarded that fauna to be lower to middle Albian, on the basis of the rudists, though both the taxonomy and the age assignment of the assemblage would now seem to merit revision.

CENOMANIAN

From a section exposed near the village of Pozo Vilató, in the Sierra de Cubitas, in northern Camagüey Province, Díaz
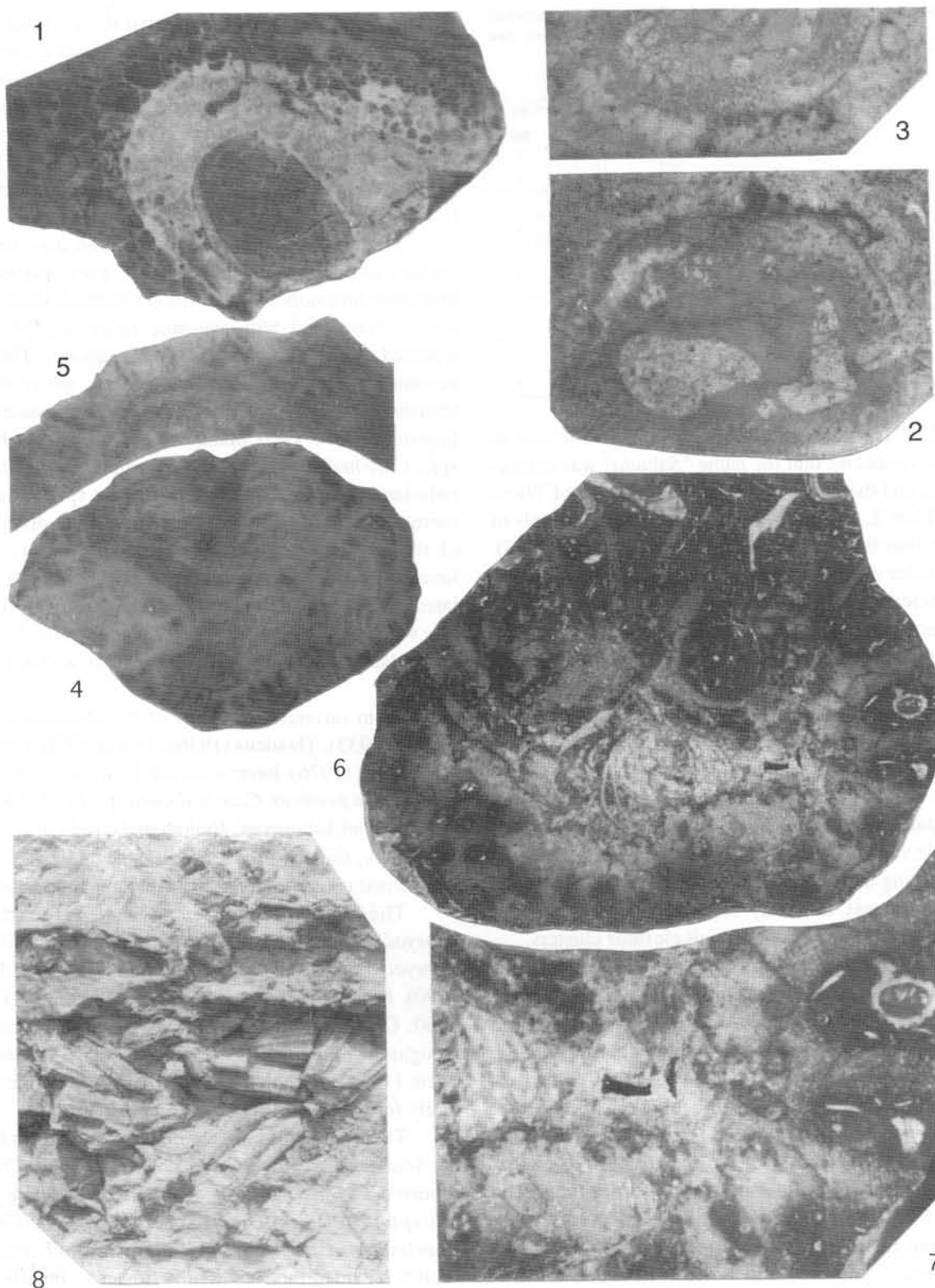
Plate 2. See caption to Plate 1 for abbreviations of repositories. Figure 1—*?Texicaprina* sp., in section across part of ?right valve, adapical view, showing ligamentary invagination at top, PWS 92/2.3 (x 1.5). Upper Albian, Guáimaro, Camagüey (Figure 1, locality 4). Figures 2, 3—*Caprinuloidea multitubifera* Palmer, in section across left valve, MNHNH-P 703 (both x 1.5). *2*, abapical view; *3*, adapical view of part of opposing section of same specimen, showing canals. Upper Albian, Guáimaro, Camagüey (Figure 1, locality 4). Figures 4, 5—*Torreites tschoppi* Mac Gillavry, section of right valve, in adapical view, PWS 92/6.1; *4*, whole valve (x 1.6); *5*, detail of postero-dorsal area, showing tight infoldings in outer shell layer. ?Santonian, Loma Yucatán, Camagüey (Figure 1, locality 5). Figures 6, 7—*Titanosarcolites alatus* Chubb, in section across one (indeterminate) valve, MNHNH-P 667; *6*, whole valve (x 1.0); *7*, detail from bottom right of same, showing canals (x 2.0). Lower-middle Campanian, Vertientes, Camagüey (Figure 1, NW of locality 7). Figure 8—*Biradiolites lombricalis* (d'Orbigny), preserved in life position, attached to the surface of a large shell fragment of *Titanosarcolites* (x 0.7). Maastrichtian, Vertientes, Camagüey (Figure 1, E of locality 7).

and Iturralde-Vinent (1981) and Iturralde-Vinent and De la Torre (1990) reported unidentified rudist debris in calciturbidites of the Vilató Formation, interpreted here as a slope deposit of Cenomanian age (Figure 1, north of locality 2). This formation is a part of the Remedios Group of the Cretaceous Bahamian carbonate platform (Figure 2).

SANTONIAN

An interesting and unusual fauna from Loma Yucatán, Camagüey Province, was reported in early studies by Sánchez-Roig (1926), Mac Gillavry (1937) and Albear (1947). Similar assemblages have been found in two localities around the Escambray Mountains in central Cuba. In all cases, the rudist-bearing limestones form lenses within volcano-sedimentary sections.

Loma Yucatán itself is a small limestone hill, projecting from a broad plain, situated NE of Camagüey city (Figure 1, locality 5), where, according to Iturralde-Vinent and De la Torre (1990), a thick limestone unit is embedded in tuffs and tuffites of the Piragua Formation (Figure 3). The whole rock mass overlies an ophiolite melange, with tectonic contact, as an isolated klippe thrust from the south. Dark grey limestones, weathering to buff coloured, varying in grain size from coarse to fine, and interbedded with probable shales or tuffites (recessive and unexposed) were observed. No orbitoids have been reported from these rocks, but Consuelo Díaz (personal communication, 1991) found, in one sample, calcisphaerids, *Stomiosphaera sphaerica*, *Pithonella ovalis*, and foraminifers, *Globotruncana* sp., as well as heterohelicids.

From these limestones, Mac Gillavry (1937) reported *Durania curasavica* (Martin), *Durania lopeztrigoi* (Palmer), *Vaccinites inaequicostatus macgillavryi* (Palmer), *Torreites tschoppi* Mac Gillavry, *Praebarrettia corrali* (Palmer), and *?Mitrocaprina* sp. To this list, it can be added *Plagioptychus* sp., collected during our field work.

The present authors regard the distinction between the two species of *Durania* cited here as questionable. The holotype of *D. lopeztrigoi* (specimen MNHNH-P320) is from this locality, and, though worn, shows the nearly cylindrical form of the right valve that Mac Gillavry regarded as typical of the species. According to Mac Gillavry, *D. curasavica* differs, among other respects, in having a widely spreading, low (inverted) conical form to the right valve. However, the growth geometry of such shells, in which a radially expansive growth phase, associated with early establishment on the substratum, could be followed by more or less cylindrical upright growth, can be expected to vary among individuals according to the particular circumstances of ambient sedimentation and the growth of near neighbours. So the criterion of attached shell shape may be unreliable to separate species. Nevertheless, other differences among the Cuban species, concerning the mean size of the cells in the outer shell layer, and the form of the radial bands, were also cited by Mac Gillavry (1937). Thus

a fuller quantitative appraisal of variability in these characters is needed to settle the question. A further striking feature of the *Durania* specimens from Loma Yucatán, already noted by Mac Gillavry (1937), is the large size reached by many of them; commissural diameters of around 30 cm are not uncommon.

Loma Yucatán is also the type locality for *V. inaequicostatus macgillavryi* (the holotype is specimen MNHNH-P222), and the taxon is extensively described and discussed by Mac Gillavry (1937) and Van Dommelen (1971), the latter employing the generic name *Pseudovaccinites* Sénesse for it. Similar specimens, from Guerrero State in southern Mexico, have been referred by Alencáster and others (1987) to *Vaccinites giganteus* (D'Hombres Firmas) (their pl. 2, figs. 4–7) and *Vaccinites* sp. (their pl. 2, figs. 1–3). The present authors consider these to compare more closely, however, with *V. i. macgillavryi*, so they might perhaps be assigned to that taxon. The modest size of the Mexican specimens, with strong external ribbing, the slight anteriorward flexure of the thin, elongate *arête cardinale* (P0) and of the oblong head of the posterior pillar (P2), and the weak pinching of the bases of the pillars are all features commonly observed within the range of variability of the Cuban specimens described by Mac Gillavry. But Mac Gillavry also noted that in his material the first pillar (P1) is almost the length of P2, while in the Mexican specimens it is appreciably shorter—a feature more typical of the European forms of the species. The Mexican specimens were recovered from limestones apparently laterally equivalent to flysch deposits with the Turonian-Coniacian foraminifers, *Clavihedbergella simplex* Morrow, *Whiteinella archaeocretacea* Pessagno and *Heterohelix* sp.

V. i. macgillavryi has also been reported (as *V. macgillavryi*) from Somalia, by Sirna and coworkers (1988) and Pons and coworkers (1992). But the specimens described and figured by them appear in all respects to compare more closely with the somewhat larger and younger (Campanian) *V. i. vermunti* Mac Gillavry, which Van Dommelen (1971) interprets as a descendent form. Thus, as in the latter, though in contrast to the former subspecies, the Somalian specimens show almost no undulation of the inner margin of the outer shell layer; they lack the anteriorward flexure of P2; they have a rounded termination to the *arête cardinale*; and they have the posterior myophore displaced ventralwards of the line of the two teeth (rather than being in line with them). Such an assignment would also be more consistent with the Campanian age (based on foraminifers) of the unit containing the Somalian specimens. Pons and others (1992) assert that the two subspecies are synonymous, but without substantiation. For the time being, it seems preferable to maintain the distinction made between them in the earlier studies of Mac Gillavry and Van Dommelen, as it might reflect a biostratigraphically useful phyletic (chronosubspecies) trend. However, further quantitative study would also be valuable.

Torreites tschoppi and *Praebarrettia corrali* are yet other taxa first described from Loma Yucatán. The present

authors have little to add to the descriptions of Mac Gillavry (1937) and Van Dommelen (1971), though two observations on the former taxon are worthy of comment. First, Professor Mac Gillavry (personal communication, 1993) has drawn our attention to the existence of radial (blind) canals within the inner shell of the left valve in this species, like those already known from *Torreites sanchezi* (Douvillé). Secondly, we have a specimen in which tight infoldings of the outer shell layer are evident (Plate 2, figures 4, 5). Though well known in *T. sanchezi*, such infoldings were believed by Mac Gillavry to be absent in *T. tschoppi*. With little doubt, then, the radial wedge-shaped structures in the outer shell layer of a right valve of *T. tschoppi* from Curaçao, noted by Van Dommelen (1971, pl. II, fig. 2), are such infoldings, also obscured by recrystallisation.

Albear (1947) and Chubb (1961) named this assemblage the *Durania* Fauna, De la Torre (1960) termed it the *Durania* and *Vaccinites* Fauna, and Iturralde-Vinent and De la Torre (1990) identified it as the *Durania curasavica* Fauna. Its age is controversial: first, being a klippe, the whole section is isolated from other potentially correlatable units; secondly, the absence of orbitoid foraminifers, regarded by Mac Gillavry (1937, p. 118) as indicative of a pre-Maastrichtian age, could be argued to be due to environmental factors; and thirdly, none of the rudist taxa present have well constrained ranges, and certainly not such as to restrict the unit to the Santonian. However, a few kilometres south of Loma Yucatán, limestones and tuffites with Santonian ammonites (*?Paratexanites* sp., *?Texasia dentatocarinata)* are found in the Piragua Formation, hinting at the possibility of isochronous shallow-water rudist-bearing facies. Nor can Mac Gillavry's argument concerning the absence of orbitoids be lightly dismissed, as they are also lacking from corresponding assemblages found in Seroe Tein-tje, Curaçao (Mac Gillavry, 1977; Biozone I - *Durania curasavica* Biozone). Mac Gillavry (personal communication, 1993) states: "In Curaçao we had several isolated limestone outcrops that, including the entire Seroe Teintje, may be olis-toliths. Some carried *Pseudorbitoides*; others (S. Teintje and Zevenbergen), which contained the *curasavica-tschoppi* as-semblage, always were devoid of larger forams". Furthermore, an association of *V. i. macgillavryi* and Santonian ammonites is known from central Cuba (Kantshev *et al.*, 1976; see below). Finally, the relatively small and unspecialized nature of the species of *Praebarrettia*, *Torreites*, and *Vaccinites* present here, compared with Campanian and Maastrichtian congeners, should be noted. This observation has been taken to support assignment to a lower stratigraphical level (*e.g.,* Van Domme-len, 1971), though arguments based on evolutionary grade, such as this, cannot be relied upon too heavily. From the various arguments given above, a Santonian age for the fauna remains the most probable, but is certainly still open to question.

In central Cuba, Palmer (1933), Mac Gillavry (1937) and Kantshev and others (1976) recorded several localities with abundant *V. i. macgillavryi*. Again, these are in dark-coloured limestone intercalations within volcano-sedimentary rocks, of

the Jarao Formation (Sancti Spiritus Province; Figure 1, local-ity 9) and of the Arimao Formation (Las Moscas Member, Cienfuegos Province; Figure 1, locality 11) (Puscharovsky, 1988).

The Jarao Formation is a sequence of volcanic flows and tuffaceous rocks with intercalated limestones that contain the *Vaccinites*. The Las Moscas Member comprises some 50 m of dark coloured, nodular bioclastic limestones, containing *V. i. macgillavryi*, together with Santonian ammonites (*Texanites* sp., *Austiniceras* sp., *Paralenticeras* sp., aff. *P. stevensi, fide* Kantshev *et al.*, 1976). The coexistence of *V. i. macgillavryi* with Santonian ammonites, lends additional support to the Santonian age assigned to the Loma Yucatán limestones, dis-cussed above.

From several localities in the north of Pinar del Río Province, Vermunt (1937a, 1937b) reported *Durania palmeri* Vermunt; but Mac Gillavry (1937) regarded the species as possibly synonymous with *D. lopeztrigoi*. Consequently, Chubb (1961) proposed that these localities could be consid-ered as equivalent to those with the *D. curasavica* Fauna. Unfortunately, we have not been able to locate these points precisely in the field. In the general area there are outcrops of the Albian-Turonian Encrucijada Formation, the Turonian-Campanian Orozco Formation, and the uppermost Campanian-lower Maastrichtian Vía Blanca Formation (Figure 1, locality 14). The second author, working in the area, has never found rudist-bearing limestones within the Encrucijada and Orozco Formations, probably because these are deep-water volcano-sedimentary units. The upper Campanian-lower Maastrichtian Vía Blanca Formation uniquely contains rudists in this area, but it is a turbidite sequence with only fragmentary and rede-posited rudist shells. It is therefore unclear whether they came from an isochronous deposit or from an older source undergo-ing erosion.

CAMPANIAN

The rudist assemblages here cited as Campanian (Chubb, 1961; Iturralde-Vinent and De la Torre, 1990) have been else-where misdated as Maastrichtian (De la Torre *et al.*, 1978). They are contained in dark-coloured limestone beds interca-lated within volcano-sedimentary rocks, and can be found from western to eastern Cuba (Pinar del Río to Las Tunas provinces; Figure 1), according to different authors (Sánchez-Roig, 1926; Palmer, 1933; Rutten, 1936a, 1936b; Thiadens, 1936a, 1936b; Mac Gillavry, 1937; Van Wessen, 1943; Hermes, 1945; etc.). The assemblage has been named the *Barrettia* Fauna (Chubb, 1956, 1961), and, latterly, the *Barrettia monilifera* Fauna (Itu-rralde-Vinent and De la Torre, 1990).

In Las Tunas and Camagüey Provinces the limestones bearing *Barrettia monilifera* Woodward are situated near the base of the Piragua Formation, as isolated thin lenses, or lenticular beds up to 40–50 m thick and several km long, suggesting that they formed as isolated platforms within the

volcanic area. De la Torre and coworkers (1978) described an outcrop of dark-coloured limestones with *B. monilifera*, interbedded within tuffs and tuffites, in Cantera Las Parras (Figure 1, locality 3). They tentatively dated this unit as Maastrichtian, because of the presence of *Chubbina cardenasensis* (Barker and Grimsdale) at another locality that was assumed by them to be stratigraphically equivalent. This conclusion was revised by Iturralde-Vinent and De la Torre (1990), who considered a Campanian age more likely, for two reasons. First, not far from Cantera Las Parras, the volcano-sedimentary sequence just described (Piragua Formation) is unconformably overlain by limestones and marls with *Titanosarcolites giganteus*, of Maastrichtian age (Cantera Cayojo; Figure 1, locality 4). The second reason was based on current opinions on the range of *B. monilifera* elsewhere. According to Van Dommelen (1971), *B. monilifera*, *sensu lato*, ranged from the late Santonian/early Campanian to the early Maastrichtian, though that species, *sensu stricto*, was dated as late Campanian in Sohl and Kollmann (1985, figs. 17–19).

From his detailed quantitative studies, Van Dommelen (1971) concluded that *B. monilifera*, *B. multilirata* Whitfield, and *B. gigas* Chubb formed a close evolutionary group, probably derived from *B. coatesi* (Chubb). He concluded that the lack of earlier data on specific variability, together with difficulties in assigning some specimens, left Chubb's (1955) assertion of their distinct specific status open to question. The patterns of morphometric variability documented by Van Dommelen (*e. g.*, 1971, Text-fig. 16) indeed strongly suggest, instead, a single phyletic lineage, showing both phyletic size increase and an increasing range of absolute morphometric variation. The latter could well be expected to accompany the former trend as a simple consequence of proportionate growth. Thus a succession of three chronospecies might be defined, with *B. coatesi* dating from the late Santonian-early Campanian (Peters Hill Formation; Robinson, 1994), *B. monilifera* continuing through some part of the Campanian, and *B. multilirata* and *B. gigas* together merely representing end-members of a wide range of variation in a single, latest Campanian to Maastrichtian, terminal chronospecies.

If these taxa are indeed merely subjective subdivisions of a single phyletic lineage, as suggested here, then some discrepancies in the ranges recognized by different authors, on the basis of typological determinations of individual specimens, are bound to have arisen. The resolution of such problems—and hence definitive ranges for the putative chronospecies named above—must await more detailed morphometric analysis of large numbers of specimens from well understood stratigraphical contexts. In Cuba, for example, *B. monilifera* has not been recorded in original (not reworked) association with *B. multilirata* and *B. gigas* (Iturralde-Vinent and De la Torre, 1990). In Jamaica, by contrast, Krijnen and others (1993) reported *B. monilifera*, *B. multilirata* and *B. gigas* from the middle Campanian, in apparent contradiction to the previous statement. But characteristically, as in Cuba,

B. monilifera is not found in association with the other two taxa, but actually in a lower stratigraphical level.

The type locality for *B. monilifera* itself is situated in the lower part of the Back Río Grande Formation in eastern Jamaica, where it is associated with *Sauvagesia?*, *Chiapasella?*, rudist fragments and *Pseudorbitoides trechmanni* (Krijnen *et al.*, 1993, fig. 15). The middle Campanian age assignment for these rocks accords well with our observations in Cuba, because the outcrops with *B. monilifera* are dark-coloured limestones intercalated within a volcano-sedimentary section, and they yield the foraminiferal genera *Pseudorbitoides* and *Sulcoperculina*. But this is not the case for the Stapleton and Green Island formations, from which *B. multilirata* and *B. gigas* were reported. The rudist-bearing limestones of the Green Island Formation are a sequence "...dominated by thick-bedded biostromal to bioclastic calcarenites and rudist rubble beds, underlain by a predominant shaly succession and overlain by sandy sequences with intercalated conglomerate horizons" (Krijnen *et al.*, 1993, p. 30). The Stapleton Formation "...is a typical fore-reef deposit..." (Krijnen *et al.*, 1993, p. 34). This type of sedimentary section, with *B. gigas* and *B. multilirata* associated with many different larger foraminiferal taxa, is common in the late Campanian-Maastrichtian interval of Cuba, in deposits unconformably overlying the volcano-sedimentary sequences (Iturralde-Vinent and De la Torre, 1990; Iturralde-Vinent, 1994). Therefore, it is strongly suspected that the age of the Stapleton and Green Island formations of Jamaica is late Campanian-Maastrichtian.

The authors' own preliminary studies of Cuban *Barrettia* specimens in the MNHNH-IGP collections, using Van Dommelen's morphometric criteria, are consistent with the above hypothesis: those coming from the older, Campanian levels (*e. g.*, in the Piragua Formation) fall comfortably within the range of *B. monilifera*, while those from younger levels may be intermediate between *B. gigas* and *B. multilirata*. Chubb's (1955) observation (cited by Van Dommelen, 1971, p. 91) that *B. monilifera* appears also to be characterized by a nearly black outer shell layer, while that in *B. gigas* tends to be buff to brown, is particularly intriguing in this respect. In Cuba, the limestones found within the volcanic sequences are dark coloured, as are also the shells of the fossils that they contain. This is not the case for the Maastrichtian limestones overlying the volcanic sequences, or those of the Bahamian platform, which are generally light coloured (Iturralde-Vinent and De la Torre, 1990). Darkening of the outer (calcitic) shell layer in rudists is commonly found where there has been considerable burial and/or heating (personal observation of the third author). Thus Chubb's supposed taxonomic distinction in this respect may merely reflect the metamorphic influence of late Campanian arc-related intrusions on the older specimens (see below). More detailed studies of the morphometric variability of *Barrettia* species in Cuba (and elsewhere) might thus prove to be of considerable biostratigraphical value.

In Camagüey Province, Iturralde-Vinent and De la Torre (1990) reported the following taxa in the faunal assemblage with *B. monilifera*: *Biradiolites acuticostatus* (d'Orbigny), *Parastroma sanchezi* (Douvillé), *"Lapeirousia" nicholasi* Whitfield and *"Antillocaprina acuticostata"*, as well as *Pseudorbitoides* sp. indet., and *Sulcoperculina* sp. indet. *"Antillocaprina acuticostata"*, cited by Iturralde-Vinent and De la Torre (1990) from this assemblage, is a *lapsus calami*.

It is noted, however, that the generic status of *"Lapeirousia" nicholasi* remains uncertain. It is often referred to in the literature as *"Durania" nicholasi*, as, for example, by Chubb (1955, 1971), who rejected it from *Lapeirousia* because of the absence of true pseudopillars. But, nor is Chubb's assignment suitable, as argued below, and Mac Gillavry (personal communication, 1993) has expressed the view that it deserves to be placed separately in a new genus. The authors agree with the latter judgement and accordingly erect the new genus *Macgillavryia* to receive it (see Systematic Palaeontology below).

The well known locality "Loma de los Caballeros", in central Camagüey province, was visited (Figure 1, locality 6; Figure 3; Mac Gillavry, 1937, locality H670), where a partial example of the association is well preserved *in situ*. Here, the limestones are 40–50 metres thick, and form part of a sharply transgressive sequence lying unconformably on Albian-Cenomanian volcano-sedimentary rocks. At the base are some 3 m of volcaniclastic conglomerates and sandstones, followed by 2 m of well-cemented, mixed volcaniclastic/bioclastic pebbly sandstones. Then follow the thick-bedded, dark grey limestones with rudists and acteonellids. Some layers are coarsely bioclastic, but most are fine-grained, though a further conglomeratic lens is intercalated in the lower part. Near the top, the unit becomes finely stratified, and fine-grained limestones are intercalated with tuffites and tuffs that come to dominate the section a little higher up (Figure 3). In the lower part of the thick limestone unit, were found abundant *Barrettia monilifera*, as well as *Biradiolites* ex gr. *acuticostatus*, *Mitrocaprina* sp. and *Macgillavryia nicholasi*, together with oysters, large acteonellids (in a band a little higher up), unidentified burrowing bivalves, and rare horizontal burrow systems. The rudists are largely in life position, implanted singly in the sediment as clingers and elevators, in the morphotype classification of Skelton and Gili (see Skelton, 1991). Upwards, the morphology of the *Barrettia* shells tends to become broader and flatter, presumably reflecting their growth responses to a progressive diminution of sediment flux. This concentration of the rudists in the basal (shallow water) calcareous deposits of a siliciclastic/carbonate transgressive sequence is remarkably similar, in palaeoecological aspect, to that seen in the transgressive neo-autochthonous sequence overlying the ophiolite in the Oman Mountains (Skelton *et al.*, 1990).

An important locality in Camagüey, NW of Vertientes, is here reported for the first time (Figure 1, NW of locality 7). In this site, lenticular beds of dark-coloured recrystallized bioclastic limestones, with *in situ* rudists, are intercalated in a section with tuffs and tuffites of the Piragua Formation, of presumed early to middle Campanian age. Farther to the south, latest Campanian-Maastrichtian age siliciclastics and limestones with *Titanosarcolites giganteus*, of the Durán and Jimaguayú formations, unconformably overlie the previous volcanic section (Figure 4). The first author collected *Titanosarcolites alatus* Chubb (Plate 2, figures 6, 7; *cf.* Van der Wal, 1978) from one of the dark limestone beds in the Piragua Formation. This type of volcano-sedimentary sequence, in the lower part of that formation, elsewhere yields the *Barrettia monilifera* Fauna in this area (as discussed above), and so the sequence discussed here is therefore most probably correlated with that assemblage zone. From thin sections in the same rocks, Consuelo Díaz (personal communication, 1994) found the Campanian-Maastrichtian *Smoutina bermudezi*, *Sulcoperculina* sp., fragments of orbitoidal foraminifera, and ostracods. This report is extremely important, because it points to the probability that some *Titanosarcolites* already existed in the Campanian in Cuba, as well as in Jamaica, where Jiang and Robinson (1989) have dated the lower part of the *Titanosarcolites*-bearing Guinea Corn Formation as late Campanian, on the basis of calcareous nannofossils—though debates persist on the biostratigraphical criteria for placing the base of the Maastrichtian here.

In the former Las Villas Province, several localities have been reported that contain the *Barrettia monilifera* Fauna. Most of them belong to the Tasajeras Group, a section of volcano-sedimentary rocks with limestone intercalations, equivalent in age and lithology to the Piragua Formation of Camagüey (Puscharovsky, 1988).
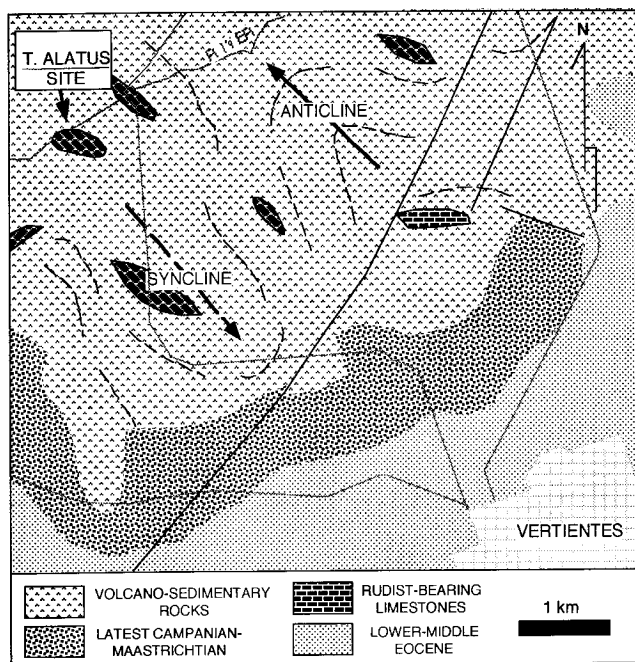

Figure 4. Geological map of the area north of Vertientes where *Titanosarcolites alatus* is found in early-middle Campanian volcano-sedimentary deposits.

The Cotorro Formation—part of the Tasajeras Group—is described as tuffs, sandstones, marls and dark coloured detrital to bioclastic limestones (Kantshev *et al.*, 1976). The rudists found in these limestones were reported as *Barrettia monilifera, Biradiolites cubensis* Douvillé, *Biradiolites* sp. cf. *B. lameracensis* Toucas, *Plagioptychus antillarum* (Douvillé), *Bournonia hispida* (Douvillé), *Chiapasella cubensis* Rutten, *Torreites sanchezi* (Douvillé) and the orbitoidal foraminifers *Vaughanina cubensis* Palmer and *Lepidorbitoides* sp. (Rutten, 1936a, 1936b, locality H143, L483; Kantshev *et al.*, 1976). The Carlota Formation (Tasajeras Group) yields a similar rudist assemblage (Mac Gillavry, 1937, locality H555). The section is composed of basaltic to andesitic flows and tuffs, with lenticular intercalations of dark-coloured limestones, 50–60 m thick, in the uppermost part of the unit. The outcrops of these formations are overlain by uppermost Campanian?-Maastrichtian siliciclastic and carbonate rocks (Kantshev *et al.*, 1976; Puscharovsky, 1988).

Recently Alencáster and Poríis (1992) have revised the status of the species of the genus *Chiapasella* in America, and concluded that *C. bermudezi, C. cubensis* and *C. pauciplicata,* all described from Cuba, are junior synonyms of *Chiapasella radiolitiformis* (Trechmann). Therefore, *Chiapasella* is actually known to be present in Campanian-Maastrichtian deposits of Mexico, Cuba and Jamaica (Krijnen *et al.*, 1993).

Various rudist localities in La Habana and northern Pinar del Río provinces have been referred to the *Barrettia monilifera* Fauna, but the assignments are strongly disputable. The first and second authors have been able to visit only a few of these localities, but have carefully matched their locations with the 1:50'000 and 1:250'000 geological maps of the area. From this evaluation, it can be concluded that specimens from the *Barrettia monilifera* Fauna have been found largely in the uppermost Campanian to lower Maastrichtian Vía Blanca Formation and equivalent sections (Figure 1, locality 13). This is a turbidite unit without carbonate beds, where rudists are usually reworked. Therefore, these rudist-bearing localities have to be restudied before a final conclusion be reached. One example of this kind of allochthonous assemblage was examined near Esperanza, in central Cuba (Figure 1, locality 12), from where several rudist taxa have been reported (Rutten, 1936a, 1936b, locality H550). The assemblage includes *Barrettia monilifera, Torreites sanchezi, Biradiolites cubensis* and *Chiapasella cubensis. Antillocaprina occidentalis* was also found. According to Chubb (1961), this is a typical Campanian locality; but it was found that the containing beds are conglomerates of Maastrichtian age, with reworked (fragmentary) rudists. In this case, as probably in most of the La Habana and northern Pinar del Río localities, the present association of fossils is a consequence of resedimentation, probably from different sources.

In the early papers of Mac Gillavry, Vermunt, Thiadens, Palmer, and others (*op. cit.*), the *Titanosarcolites* and *Barrettia* limestones were commonly included in the "Habana Forma-

tion" *sensu* Palmer (1934). Consequently the age of the *Barrettia monilifera* Fauna was usually misidentified as Maastrichtian (Douvillé, 1926, 1927; Mac Gillavry, 1937; De la Torre, 1960; De la Torre *et al.*, 1978). In fact, the *Barrettia monilifera* limestones belong to the partially metamorphosed volcano-sedimentary sequences of Santonian to middle Campanian age (*e. g.*, in the Piragua Formation, as described above, and the Tasajeras Group and equivalents), which are intruded by huge granitoid bodies. Very often, these rocks are recrystallized, and metasomatic mineralization may be present. This island arc volcano-plutonic complex is unconformably overlain by clastics of latest Campanian to Maastrichtian age (Durán, Vía Blanca and equivalent formations), with debris indicating that deep erosion of the volcano-plutonic pile had taken place (Bronnimann and Rigassi, 1963; Iturralde-Vinent *et al.*, 1989; Iturralde-Vinent and De la Torre, 1990). Moreover, with the *Barrettia monilifera* Fauna are found *Pseudorbitoides* sp. indet., and *Sulcoperculina* sp. indet. Such a limited association is atypical for the Maastrichtian, where a much more differentiated group of orbitoidal foraminifers usually accompanies the *Titanosarcolites giganteus* Fauna (next section, and see Iturralde-Vinent and De la Torre, 1990; Table 2). Therefore, the authors agree with Chubb (1961) and Iturralde-Vinent and De la Torre (1990), in assigning the *Barrettia monilifera* Fauna to the Campanian, and indeed probably just the lower to middle Campanian, at least in Cuba, and probably in Jamaica, as discussed previously.

MAASTRICHTIAN

The most widely developed rudist faunas in Cuba are those of the Maastrichtian. Assemblages of this age are found both in the Bahamian platform limestones and in the calcareous deposits that overlie the extinct volcano-plutonic island arc suite (Figures 1 and 2).

Maastrichtian rudist-bearing rocks of the Bahamian carbonate platform have been reported from the Sierra de Cubitas, in northern Camagüey Province (Figure 1, locality 2; Iturralde-Vinent and De la Torre, 1990). The locality at Paso de Lesca, beside the road from Camagüey to Sola, was visited, and were found exposures of platform margin facies, characterized by thickly bedded, partially recrystallized shelly bioclastic floatstones and fine to medium grained grainstones, white to light greyish in colour. Some beds contain abundant large-sized *Biradiolites lombricalis* (d'Orbigny) in living position, as clustered elevators, while thin floatstone layers include transported *Titanosarcolites* aff. *alatus, Antillocaprina* sp., *Mitrocaprina* sp., and various undetermined radiolitids, along with typically Maastrichtian orbitoidal foraminifera (see Iturralde-Vinent and De la Torre, 1990, tab. 2). These beds are from the upper part of the Purio Formation (Remedios Group), and reach about 100 m in thickness.

In the Maastrichtian slope and basinal deposits found south of the Bahamian platform (Camaján and Amaro Forma-

Table 2. Cuban rudist biozones.

Age	Biozone	Typical rudist taxa
Lower Aptian	Amphitriscoelus waringi	Amphitriscoelus waringi Harris and Hodson Offneria sp. cf. O. interrupta Paquier Caprina douvillei Paquier ?Pachytraga paradoxa (Pictet and Campiche)
Upper Albian	Tepeyacia corrugata	Tepeyacia corrugata Palmer Kimbleia albrittoni (Perkins) ?Texicaprina sp. Caprinuloidea multitubifera Palmer
?Santonian	Durania curasaviva	Durania curasavica (Martin) D. lopeztrigoi (Palmer) Vaccinites macgillavryi (Palmer) Torreites tschoppi MacGillavry Praebarrettia corrali (Palmer)
Campanian	Barrettia monilifera	Barrettia monilifera Woodward Torreites sanchezi (Douvillé) Parastroma sanchezi (Douvillé) Biradiolites cubensis Douvillé B. sp. (gr. B. acuticostatus [d'Orbigny]) Bournonia sp. Macgillavryia nicholasi (Whitfield) Plagioptychus sp.
Uppermost Campanian-Maastrichtian	Titanosarcolites giganteus	Titanosarcolites giganteus (Whitfield) Antillocaprina spp. Mitrocaprina tschoppi (Palmer) Praebarrettia sparcilirata (Whitfield) Barrettia multilirata-gigas Parastroma guitarti (Palmer) Hippurites mullerriedi Macgillavryia nicholasi Biradiolites lombricalis (?syn. B. mooretownensis Trechmann) Biradiolites sp. (gr. B. acuticostatus) Bournonia spp.

tions), unidentified rudist debris has been recorded from the calcirudaceous to calcarenaceous deep water units that crop out in several localities in northern Central Cuba (Pszczolkowski, 1986; Iturralde-Vinent and De la Torre, 1990). Similar deposits have been described from the Peñalver (Bronnimann and Rigassi, 1963) and Cacarajícara (Pszczolkowski, 1986) formations, in western Cuba, but these last are not related to the Bahamian platform, but overlie the extinct volcanic arc. The rocks under consideration are megaturbidites, interpreted as tsunami deposits (Pszczolkowski, 1986).

The most widely developed Maastrichtian deposits with abundant rudists are those unconformably overlying the volcanic-sedimentary sections of the Cretaceous volcano-plutonic island arc, mainly exposed in the central part of the island (Figure 1). These units have received very different local formational names, but in general are of two types: a lower siliciclastic facies with rare calcareous intercalations, and a partially isochronous facies of limestones and marls that ultimately dominate the top of the sections (Figure 3). The age range of these rocks has been generally identified as latest

Campanian to Maastrichtian (see, for example, Bronnimann and Rigassi, 1963, for the Vía Blanca/Peñalver Formations; and Iturralde-Vinent and De la Torre, 1990, for the Durán/Jimaguayú Formations; Iturralde-Vinent, 1994). As noted previously, similar sections in Jamaica have been referred to the late Campanian and Maastrichtian (Río Grande and Guinea Corn Formations) by Krijnen and others (1993).

In eastern Cuba Titanosarcolites giganteus has been reported from several localities in the Maastrichtian Cañas Formation, and reworked in Maastrichtian-Paleocene olistostromes (Figure 1; Cobiella et al., 1984). Also, De la Torre and coworkers (1978) described Titanosarcolites limestones from the area north of Holguín and near Las Tunas (Figure 1). From marls at locality 4 on Figure 1 (Cayojo Member = Jimaguayú Formation), they described an association of diverse Maastrichtian orbitoidal foraminifers, together with Praebarrettia sparcilirata (Whitfield), Plagioptychus tschoppi Palmer (= Mitrocaprina; see Mac Gillavry, 1937), Titanosarcolites sp., and Barrettia multilirata Whitfield (but see the earlier discussion of the status of the latter taxon).

In Camagüey Province, Iturralde-Vinent and De la Torre (1990) listed, from the Durán and Jimaguayú Formations, Titanosarcolites giganteus, Biradiolites mooretownensis Trechmann (?= B. lombricalis), Mitrocaprina tschoppi (Palmer), Antillocaprina annulata (Palmer), Bournonia thiadensi Vermunt, B. cancellata (Whitfield), Parastroma guitarti (Palmer) and Praebarrettia sparcilirata, along with a large number of Maastrichtian foraminifers. At a locality ENE of Vertientes (Figure 1, locality east of 7), the authors found, in marly floatstones of the Jimaguayú Formation (Figure 3), Titanosarcolites giganteus, Biradiolites lombricalis (Plate 2, figure 8), Macgillavryia nicholasi (see later discussion of this taxon), Parastroma guitarti, Praebarrettia sp., Mitrocaprina sp., Apricardia sp., and "Bournonia" sp. cf. B. excavata (d'Orbigny), together with small oysters, cerithiid gastropods, corals and rare echinoids (Goniopygus supremus Hawkins; S.K. Donovan, personal communication, 1992; see Donovan [1990], for records of the species from the Titanosarcolites Limestone of Jamaica). In the outcrop, the shells of Titanosarcolites and the other large rudists show signs of transport (breakage, wear and overturning), while many of the smaller forms (Biradiolites, "Bournonia", Apricardia, the oysters and the corals) are preserved in life position, commonly attached to the surfaces of the larger rudist shell fragments (Plate 2, figure 8). From San José de los Jíbaros, a locality two kilometres to the east, an age equivalent deposit includes Barrettia sp. cf. B. multilirata, Parastroma guitarti and Titanosarcolites giganteus. Similar sheet-like marly limestones, with a mixed assemblage of transported larger rudists (especially Titanosarcolites) and smaller in situ forms, have been studied by the third author in the Guinea Corn Formation of the Central Inlier in Jamaica. The mixing of faunal elements there is attributed to the lateral migration of low, shallow banks, from the top surfaces of which the larger shells were occasionally swept (by

storm currents), to be stranded in the intervening marly troughs, where the smaller taxa thrived (Skelton *et al.*, 1993, and in preparation).

West of Ciego de Ávila (Figure 1, locality 8), the uppermost Campanian-Maastrichtian marls and marly limestones of the Jimaguayú Formation contain *Antillocaprina annulata* (extremely abundant), *A. pugniformis* (Palmer), *Mitrocaprina tschoppi*, and *Praebarrettia sparcilirata* (Mac Gillavry, 1937). This is the type area for both of the *Antillocaprina* species; whether or not these—and other "species" of this genus—are really separate, or merely represent variation within a single biological species, requires proper morphometric analysis. This assemblage probably developed in a more restricted environment than those with the recumbent rudists *(Titanosarcolites)*.

In the former Las Villas Province—west central Cuba— there are many outcrops of Maastrichtian rudist-bearing deposits, but only one of the authors—the second— has visited some of them. Here, despite local formational names, the sequences are almost identical to those in Camagüey Province (Figure 1, around locality 10). From two localities (H624 and H627), Mac Gillavry (1937) reported *Titanosarcolites giganteus*, *Biradiolites aquitanicus* Toucas, *Bournonia* sp., *Praebarrettia sparcilirata* and *Antillocaprina* sp.

West of the city of Pinar del Río (Figure 1, locality 15), a peculiar assemblage was described from the San Juan y Martínez Formation (Vermunt 1937a, 1937b; localities H774, V614), including *Titanosarcolites giganteus*, *Bournonia* sp., *B. thiadensi*, *B.* cf. *B. africana*, *Chiapasella pauciplicata* Müllerried, *Praebarrettia sparcilirata*, *Antillocaprina* sp. cf. *A. annulata*, and *Hippurites mullerriedi* Vermunt. One section measured by the first author near these localities yielded *Titanosarcolites giganteus*, *Antillocaprina annulata*, *Mitrocaprina* sp., *Plagioptychus* sp., *Biradiolites* sp., *Parastroma* sp., and *Radiolites* sp. in association with Maastrichtian larger foraminifers. From the same area Lupu (1975) described several rudist biozones with very different rudist taxa. Some of Lupu's specimens have been examined at the collection of the Museo Nacional de Historia Natural-Instituto de Geología y Paleontología, and the first author has visited the locality. Generally the fossil material is poorly preserved and difficult to identify, and the type material cannot always be located, because it was not properly labelled by Lupu.

Lupu (1975) proposed four rudist biozones: a *Bournonia* Zone (upper Campanian), a *Praebarrettia* Zone (lower? Maastrichtian), an *Antillocaprina* Zone (middle-upper Maastrichtian) and a *Titanosarcolites* Zone (Maastrichtian). The names of these biozones are impractical, because these taxa have longer stratigraphical ranges than those asserted for the zones (as discussed above). The same author also assigned some material, without adequate description or illustration, to taxa not previously recognized from the New World, such as *Dictyoptychus* and *Joufia*. No specimens assigned to *Dictyoptychus* were found in the MNHNH-IGP collection, but the so-called *"Joufia"*, which the authors did locate, can be rejected as an erroneous identification of a *Sauvagesia* sp. Likewise, the identification of *Lithocalamus*, as a new report for Cuba, is dubious. Clearly, the rudist fauna studied by Lupu (1975) must be carefully revised in the future, and the identifications, as they stand at present, regarded as unreliable.

In La Habana and Matanzas provinces, as in northern Pinar del Río Province (Bahía Honda region), the rudist-bearing deposits are turbiditic conglomerates, so all specimens found are reworked (Figure 1, localities 13, 14). It appears that in both the Vía Blanca and the Peñalver Formations, rudists from different assemblages and of different ages were mixed together during the sedimentary process. This is the reason why Palmer (1933), Vermunt (1937a, 1937b) and Chubb (1961) have described taxa from both the *Barrettia monilifera* and *Titanosarcolites giganteus* faunas in these provinces.

The beds that contain the *Titanosarcolites giganteus* Fauna have been dated as Maastrichtian since Douvillé (1926, 1927) and Sánchez-Roig (1926), and up to Chubb (1956, 1961), De la Torre (1960), and Iturralde-Vinent and De la Torre (1990). As noted earlier, however, an extension of the range of *Titanosarcolites* itself into the latest Campanian can now be recognized in parts of Jamaica (Jiang and Robinson, 1989), and probably into the mid Campanian in central Cuba. Therefore, *Titanosarcolites* can be accepted as a Campanian and Maastrichtian genus, with the taxon *T. giganteus* restricted to the latest Campanian-Maastrichtian. The rudist assemblage with *Antillocaprina annulata* found in Ciego de Ávila (Figure 1, locality 8) is an age equivalent facies-variant of the *T. giganteus* limestone, as is the one with *Biradiolites lombricalis* plus *T. alatus* from the Bahamas platform (Figure 1, locality 2).

SYSTEMATIC PALAEONTOLOGY

During the course of this work, it became apparent that the well known Caribbean taxon widely referred to in the literature as *"Durania" nicholasi* (Whitfield) remained in a most unsatisfactory limbo as far as its generic identity was concerned (as noted above). Therefore it was felt to be appropriate to resolve the issue formally here, by erecting a new genus for this distinctive species.

Family Radiolitidae A. d'Orbigny, 1847
(see Manceñido *et al.*, 1993)
Subfamily Biradiolitinae Douvillé, 1902

Macgillavryia new genus

Name—In appreciation of Professor Henry Mac Gillavry's valuable contributions to Caribbean geology, especially that of Cuba, and to rudist palaeontology.

Type species—*Radiolites (Lapeirousia) nicholasi* Whitfield (1897, p. 186–188, pls. 6–9).

Diagnosis—Large radiolitid with broad cylindrico-conical right valve and low domed left valve. Lamellose outer shell layer of the right valve much expanded, spreading directly outwards most of the way around the body cavity, and bearing impressions of bifurcating radial vessels on its growth surface. Posterior zone embayed, showing pronounced folds associated with the external radial bands: growth surface corresponding to ventralward radial band depressed, to yield a wide, flat-bottomed, downfold; from there interband rises steeply to a slightly flattened summit corresponding to dorsalward band, from which growth surface drops gently down again on its dorsal side. Radial bands unornamented, externally, apart from coarse growth rugae, with concave interband. Outer shell structure of right valve finely celluloprismatic to compact: cells relatively thick-walled, of irregularly reticulate-amoeboid to denticulate plan. Internally, neither ligament nor *arête cardinale* present. Two teeth only, in left valve, sliding into ridged grooves on inner wall of right valve. Opposing adductor scars, on myophores of left valve and inner shell wall of right valve, likewise with interdigitating ridges and grooves.

Remarks—Mac Gillavry (1937, p. 40) first drew attention to the distinctive arrangement of the radial bands in this taxon, in discussing his "Genus *Bournonia*, new section - sp. 4". He illustrated this aspect in a specimen (shown in his pl. 8, fig. 10) from the "Habana Formation" in the eastward extension of the Sierra Najassa, Camagüey (his locality H 689). The myocardinal apparatus was shown in a sketched section (*idem.*, p. 40) across another specimen from the same locality. Among the other species he included in the new taxon was *Radiolites (Lapeirousia) nicholasi* Whitfield (1897). The author of the latter species had alluded graphically to the relatively embayed posterior zone (which he erroneously described as "cardinal") in referring to the top view of the shell as presenting "a somewhat reniform outline" (Whitfield, 1897, p. 186). The myocardinal apparatus was well illustrated by Whitfield (*op. cit.*, pls. 8 and 9) in an excavated left valve. The illustration of the radial bands given by Whitfield (his pl. 7, fig. 2), however, is somewhat unclear, but their arrangement is better shown by Chubb (1971, pl. 44, fig.1, pl. 45, fig. 1) in a topotype specimen (from Haughton Hall, Green Island, Hanover, Jamaica). Although the authors have not as yet inspected Mac Gillavry's specimens, it is evident from his detailed description, as well as our own study of other, closely similar specimens from Cuba, that these all belong to Whitfield's species (see the synonymy below).

The generic attribution of this species has had a chequered history. It was referred by Whitfield to *Lapeirousia*, but this was rejected by Chubb (1955, 1971), because of its lack of pseudopillars and oscules. The latter author preferred to assign the species to *Durania*, a practice widely followed in the literature thereafter; Mac Gillavry's earlier reference to *Bournonia* was also rejected by Chubb on the grounds that the latter genus "has a quadrangular cell pattern, a flattened anterior side, and siphonal bands in the form of costae not grooves" (Chubb, 1971, p. 201). But Chubb (1971, p. 200), following

Whitfield (1897, p. 187), was himself in error in supposing that the latter's species had straightforwardly polygonal cells. This is not the case: Jamaican topotype material (see description below), reveals that the cell pattern conforms well with that described by Mac Gillavry (1937, p. 40–41), from his Cuban material, as "irregularly reticulated" (with reference to his figured specimen) or "discontinuous, dissolved as it were into series of points or vermiculations". *Pace* Chubb, then, the pattern contrasts markedly with that of *Durania* (which does have polygonal cells), and is in fact somewhat similar to the irregularly "amoeboid" cell pattern recognized in certain biradiolitines by Amico (1978). Indeed, Mac Gillavry, himself, had noted (1937, p. 41, footnote 14) the common presence of such denticulated structure in *Biradiolites* and *Bournonia*. Thus the cell pattern, as well as the simply folded, unornamented, form of the radial bands, of the present taxon support its inclusion in the Subfamily Biradiolitinae.

Nevertheless, the growth surface of the outer shell layer corresponding to the ventralward radial band in the right valve of *Bournonia bournoni* (Des Moulins)—the type species of that genus—is consistently upfolded (similarly to that in *Praeradiolites*), in contrast to the characteristically downfolded pattern seen in Whitfield's species. None of the currently recognized species of *Bournonia*, moreover, shows such exaggerated expansion of the outer shell layer. Mac Gillavry's (1937) recognition of the distinctive nature of the present taxon therefore seems justified, indeed meriting the erection of a new genus (H.J. Mac Gillavry, personal communication, 1993), as formally proposed here.

Macgillavryia nicholasi (Whitfield, 1897)
(Plate 3, figures 1–5)

Synonymy

1897 *Radiolites (Lapeirousia) nicholasi* Whitfield, p. 186–188, pls. VI–IX, all figures.

1924 *Lapeirousia nicholasi* Whitfield, Trechmann, p. 405–406.

1926 *Lapeirousia nicholasi* Whitefield (*sic*), Sánchez-Roig, p. 91–93.

1937 *Bournonia*, new section, sp. 4, Mac Gillavry, p. 40–42, pl. 8, fig. 10.

1955 *Durania nicholasi* (Whitfield), Chubb, p. 2–3.

1971 *Durania nicholasi* (Whitfield), Chubb, p. 199–201, pl. 43, fig. 6 (copy of Whitfield, 1897, pl. VII, fig. 2); pl. 44, fig. 1, pl. 45, fig. 1; pl. 46, figs. 1, 2 (new photographs of the left valve figured by Whitfield, 1897, in his pl. IX).

?1995 *Durania* aff. *nicholasi* (Whitfield), Schumann, pl. 38, fig. 4, pl. 39, fig. 2.

Type material—No lectotype appears yet to have been formally proposed from among Whitfield's (1897) four illustrated syntypes (housed in the American Museum of Natural History palaeontological collections, accession number 9675, according to

Plate 3. Macgillavryia Skelton, new genus, herein: type species *M. nicholasi* (Whitfield). See caption to Plate 1 for abbreviations of repositories. Figures 1, 2—*Macgillavryia nicholasi* (Whitfield), reproductions of Whitfield's (1897) original plate figures showing the lectotype designated herein: *1*, pl. VI, fig. 1, view of both valves, looking down obliquely onto the low domed left valve and the broad right valve margin; *2*, pl. VII, fig. 1, radial section across both valves (along the cut shown in fig. 1), passing through the relatively depressed shell wall of the ventralward radial band at the left. Both approximately x 0.25 of specimen size. Campanian *Barrettia* Limestone of Haughton Hall Estate, Green Island Inlier, Jamaica. Figure 3—*M. nicholasi*, detail of cell pattern on growth margin of right valve, in topotype specimen from *Barrettia* Limestone of Haughton Hall Estate, Green Island Inlier, Jamaica, NHM-unregistered specimen from W.J. Kennedy collection (field number 78/2) (x 10). Figures 4, 5—*M. nicholasi*, adapical view of right valve, partially covered by crushed remains of left valve. Specimen MNHNH-P315, locality unrecorded. *4*, whole specimen (x 0.4); detail of postero-ventral area, showing radial bands (vb = ventralward band; db = dorsalward band) and crushed remains of left valve (lv) covering part of right valve margin (x 0.6).

Chubb [1971]). That illustrated by Whitfield in his pl. VI, fig. 1, and pl. VII, fig. 1, is accordingly selected here, in view of the relatively complete preservation of both valves: Whitfield's original plate figures of the specimen are reproduced in this work as Plate 3, figures 1 and 2.

Described material—The palaeontological collections of the Museo Nacional de Historia Natural, La Habana, contain a well preserved specimen (MNHNH-P 315) from Cuba, though regrettably of unrecorded provenance: this is illustrated in Plate 3, figures 4, 5. A fragment of the distinctive outer shell layer of the right valve, collected from the type locality in Jamaica (*Barrettia* Limestone [Campanian] of Haughton Hall Estate, Green Island Inlier, Jamaica) by W.J. Kennedy, and housed in the Natural History Museum, London (unregistered), is also illustrated (Plate 3, figure 3), to show the distinctive cell pattern of the species.

Description—The Cuban specimen illustrated here (Plate 3, figures 4, 5) conforms closely with the description and illustration of *Bournonia*, new section, sp. 4, given by Mac Gillavry (1937, p. 40–42, pl. 8, fig. 10). The diagnostic arrangement of the radial bands, in particular, is well shown (Plate 3, figure 5): the broadly concave ventralward band corresponds with a depressed gutter on the right valve margin, while the slightly projecting dorsalward band is matched by a strong upward fold of the margin (though its summit has broken off in our specimen). A narrow, centrally concave, interband lies between them. The same features are also clearly displayed in the Jamaican specimens illustrated by Chubb (1971): the depressed ventralward band is well shown in the topotype specimen illustrated in his pl. 44, fig. 1, pl. 45, fig. 1 (though the other band and interband have broken off in that specimen); the salient dorsalward band can be seen immediately to the left of his label "S" on the reproduction of one of Whitfield's figures shown by Chubb in his pl. 43, fig. 6. Regarding the latter figure, Chubb appears to have erroneously labelled the concave interband as "E". The true ventralward band is almost certainly represented by the depressed laminae to the left of that label.

In the Cuban specimen, the right valve margin in the area of the ventralward band is partially covered by the crushed remains of the thin rim of the left valve's compact calcitic outer shell layer (Plate 3, figure 5). This preservational relict suggests that the entire margin of the right valve may originally have been covered by a thin flange of the left valve rim, contradicting the idea promoted by Chubb (1971, p. 200) and subsequent authors that the margin of the left valve did not fully cover that of the left.

The cell structure of the outer shell layer of the right valve, shown by the Jamaican topotype fragment illustrated here in Plate 3, figure 3, is very fine, though the cells are, for their size, relatively thick-walled. They are of irregular, concentrically elongate, and in places reticulate form, though breaking down locally to a denticulate pattern. The pattern thus matches precisely that described by Mac Gillavry (1937) from his Cuban specimens.

Discussion—In view of the close similarities between the Cuban and Jamaican specimens noted above, all may be safely assigned to Whitfield's species—the type of the new genus, *Macgillavryia*.

The species is known to accompany both the Campanian *Barrettia monilifera* and the Maastrichtian *Titanosarcolites giganteus* faunas (see above), in the Caribbean province. The specimens illustrated by Schumann, from Oman, certainly appear superficially similar, though further details of the arrangement of the radial bands, and of the cell pattern, in his material, are needed before a firm identification can be established. If confirmed, the record would be of considerable palaeobiogeographical interest, lending further weight to the trans-Pacific faunal connection for this interval detected by Skelton and Wright (1987).

CONCLUSIONS

1. In Cuba rudist-bearing rocks are found in two major geologic settings: in the deposits of the Cretaceous Bahamian carbonate platform, and within the volcano-sedimentary rocks of the Cretaceous volcanic arc.

2. Within the Bahamian carbonates, known rudist-bearing deposits are of early Aptian, Cenomanian and Maastrichtian ages. As the platform is strongly deformed and the sections superimposed by thrusting, it is possible that the lack of rudist-bearing deposits of ages other than those recorded here, is due to the limited availability of adequate outcrops, not to original environmental limitation.

3. In the Bahamian carbonate platform the lower Aptian assemblage includes *Amphitriscoelus waringi* Harris and Hodson, *Offneria* sp. cf. *O. interrupta* Paquier, *Caprina douvillei* Paquier, and ?*Pachytraga paradoxa* (Pictet and Campiche); the Cenomanian level includes unidentified rudist fragments in calciturbidites with planktonic microfossils; and the Maastrichtian assemblage includes *Biradiolites lombricalis* (d'Orbigny), *Titanosarcolites* sp. aff. *T. alatus* Chubb, *Antillocaprina* sp., *Mitrocaprina* sp., and orbitoidal foraminifers.

4. There are four levels of rudist-bearing limestones associated with the Cretaceous volcanic arc. Three of them (of late Albian, ?Santonian and early-mid Campanian ages) are found as dark-coloured limestone intercalations in the volcano-sedimentary suite, while the fourth, latest Campanian-Maastrichtian, level lies with angular unconformity on the previous suite. The consistency in age and stratigraphical position of these limestones in different areas of Cuba suggests that their development was probably related with sea level changes and/or with episodes of decline in the volcanic activity of the arc, that favoured the evolution of small isolated platforms. The fourth level, latest Campanian-Maastrichtian in age, developed as a larger platform across the area of the extinct Cretaceous arc.

5. The rudist assemblages within the volcanic arc are as follows: The upper Albian level is characterized by *Tepeyacia corrugata* Palmer, *Kimbleia albrittoni* (Perkins), ?*Texicaprina* sp.,

and *Caprinuloidea multitubifera* Palmer. The ?Santonian fauna includes two possibly synonymous species of *Durania*, *D. curasavica* (Martin) and *D. lopeztrigoi* (Palmer), as well as *Vaccinites inaequicostatus macgillavryi* (Palmer), *Torreites tschoppi* Mac Gillavry, *Praebarrettia corrali* (Palmer), and plagioptychids. The Campanian fauna includes *Barrettia monilifera* Woodward, *Torreites sanchezi* (Douvillé), *Parastroma sanchezi* (Douvillé), *Biradiolites cubensis* Douvillé, *Biradiolites* sp. (group of *B. acuticostatus* [d'Orbigny]), *Bournonia* sp., *Macgillavryia nicholasi* (Whitfield) (see 9, below), *Plagioptychus* sp., *Mitrocaprina* sp., as well as *Titanosarcolites alatus* and other, minor taxa. The latest Campanian-Maastrichtian level represents post volcanic arc platform deposits where either *Titanosarcolites giganteus* (Whitfield) or *Antillocaprina* spp., may be particularly abundant, together with *Mitrocaprina tschoppi* (Palmer), *Praebarrettia sparcilirata* (Whitfield), *Barrettia multilirata* Whitfield (of which *B. gigas* Chubb is a probable synonym), *Parastroma guitarti* (Palmer), *Hippurites mullerriedi*, *Macgillavryia nicholasi*, *Biradiolites lombricalis* (?syn. *B. mooretownensis* Trechmann), *Biradiolites* sp. (group of *B. acuticostatus*), *Bournonia* spp., and some other, minor taxa.

6. It is suggested that *Barrettia* species can be useful as biostratigraphic markers for the Santonian-Maastrichtian interval. Three chronospecies might be defined, with *B. coatesi* from the late Santonian-early Campanian, *B. monilifera* in the Campanian, and with *B. multilirata* and *B. gigas* together merely representing end-members of a wide range of variation in a single, latest Campanian to Maastrichtian terminal chronospecies.

7. It was found that in Cuba the genus *Titanosarcolites* appears to range from within the Campanian to the Maastrichtian, with *T. alatus* extending through the whole range of the genus and *T. giganteus* only through the latest Campanian-Maastrichtian.

8. In Cuba, the rudist assemblages described above proved useful for stratigraphical correlations: the *Amphitriscoelus waringi* Fauna for the lower Aptian, the *Tepeyacia* corrugata Fauna for the upper Albian, the *Durania curasavica* Fauna for the ?Santonian, the Barrettia monilifera Fauna for the Campanian, and the *Titanosarcolites giganteus* Fauna for the uppermost Campanian-Maastrichtian (Table 2). These biozones are based on the full range distributions of the named taxa, but the other taxa listed are commonly also found in original association. More refined rudist biozones are impractical in the present time and will require additional field work and taxonomic research. Some of these biozones are perfectly traceable into other areas of the Caribbean region, according to the personal experience of the authors.

9. A new genera *Macgillavryia* is introduced here for the taxon previously known as *Radiolites* (*Lapeirousia*) *nicholasi* Whitfield, or "*Durania*" *nicholasi*.

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